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Resolving Ambiguities at the Bi_2Te_3/GaAs Interface with Atomic Resolution EDS

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Bismuth telluride, Bi_2Te_3, is a common thermoelectric employed in power generation and refrigeration. Recently, topological insulating properties of Bi_2Te_3 have lead to exciting prospects for these materials in fields of spintronics and quantum computing [1]. As film thickness decreases, properties become dominated by surface and interface characteristics. Thus, the interface structure of these materials can greatly influence both thermoelectric and topologically insulating properties. We will demonstrate that atomic resolution EDS provides essential information to interpret the interface structure and chemistry.

In this talk, we will examine high quality epitaxial 6-fold (001) Bi_2Te_3 thin films grown on 4-fold (001) GaAs substrates, even with seemingly incompatible symmetry and lattice mismatch across the interface [2]. We will report the interface structure and chemistry of Bi_2Te_3 thin films on (001) GaAs substrates grown by metallorganic chemical vapor deposition (MOCVD) [3]. A state-of-the-art probe corrected FEI Titan G2 STEM with a Super-X detector was operated at 300kV for atomic-resolution high-angle annular dark-field (HAADF) imaging and 80kV for atomic-resolution energy dispersive x-ray spectroscopy (EDS). As seen in Figure 1(a), an anomalous interfacial monolayer is observed at the GaAs/Bi_2Te_3 interface. An intuitive Z^2 interpretation suggests that this column contains heavy elements, namely bismuth. The total number of atoms presiding in these columns, however, also contributes to the intensity in HAADF; therefore, HAADF only provides an ambiguous interpretation.

By means of atomic resolution EDS, we will clearly reveal the chemical composition of this interface and resolve the HAADF ambiguity. Figure 2 clearly shows tellurium dominating the EDS signal at the interface. Furthermore, we will discuss how this layer reacts with gallium to form a quarter unit cell of Ga_2Te_3. This replacement removes dangling bonds providing the platform for subsequent Bi_2Te_3 growth. Finally, through the critical combination of HAADF and EDS, these results provide significant insight into the growth for high quality 6-fold-symmetry Bi_2Te_3-based films on 4-fold-symmetry GaAs substrates.

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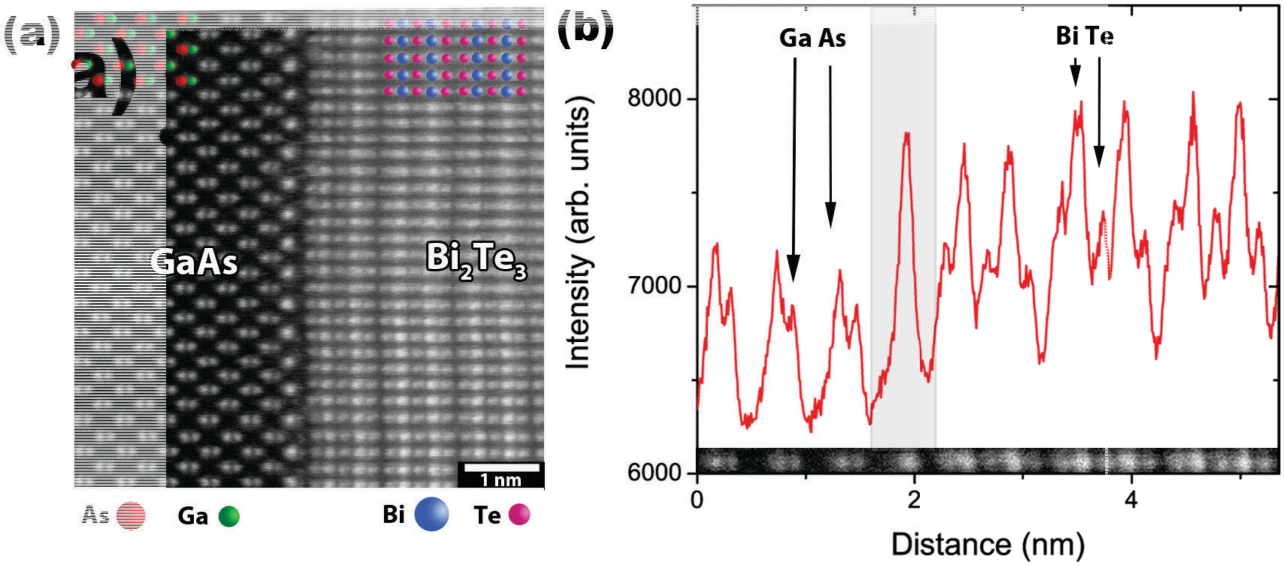

Figure 1. (a) HAADF STEM image of the atomically abrupt GaAs (left)/ Bi_2Te_3 (right) interface viewed down $\langle 110 \rangle_{GaAs}$. Note the line of bright atomic columns at the interface. b) Intensity profile across the Bi_2Te_3/GaAs interface. The identities of atomic columns are denoted and the highlighted region indicates the interface.

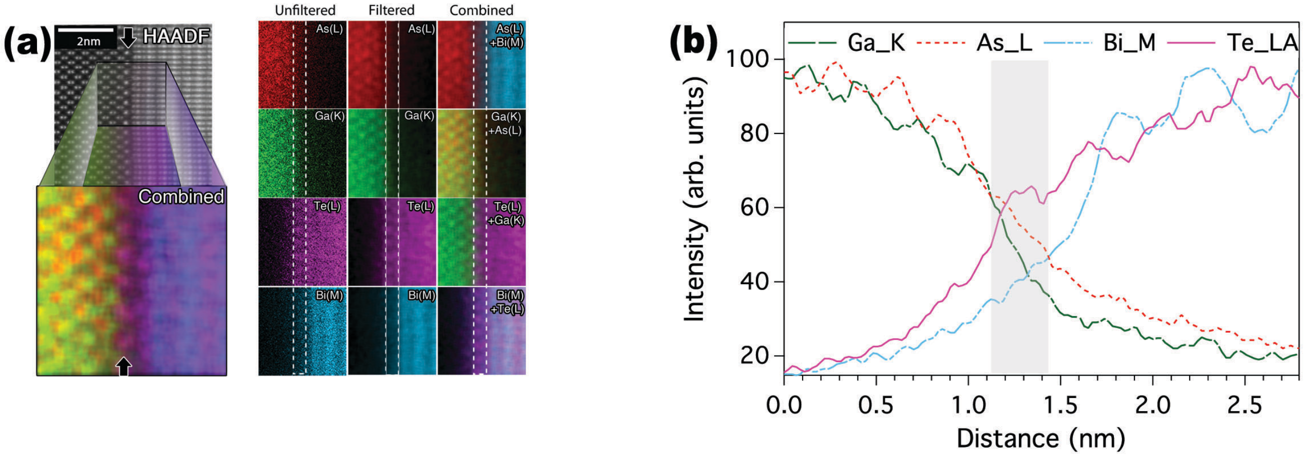

Figure 2. (a) Atomic resolution EDS mapping results at the interface of Bi_2Te_3/GaAs. Dotted lines indicate the interfacial region. (b) EDS line profile across the interface shown from (a). The images show that Te dominates the signal at the interface.